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Psychological and Physiological Predictors of Resilience in Navy SEAL Training

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ABSTRACT

This research examines resilience from both cognitive and physiological perspectives and the relative importance of resilience for progression within an extremely physical training environment for 116 individuals. Our study provides a unique contribution as an examination of the combined effects of psychological and physiological resilience in the success of individuals in the first phase of a military special operations training course, the Navy's Basic Underwater Demolition/SEAL (BUD/S) course. Our study used the Connor-Davidson Resilience Scale (CD-RISC) for the psychological assessment and a blood sample to measure the concentrations of cortisol, DHEA and BDNF, each associated with stress adaptation and neuronal integrity. Our contributions include: heeding the call for more extensive research for resilience, examining physiological markers as predictors in training situations, combining psychological and physiological resilience into a single metric to assess resilience, and providing empirical support for the vital role of resilience in both stamina and persistence in training. Our findings indicate that both psychological and physiological resilience can be important predictors of persistence individually, but combining the measures provides a more holistic view to predict the success of an individual in this intensive training program. The present study has implications not only for the military community, but also for those individuals seeking elite performance in a broad array of fields, like professional athletes, CEO's, and emergency response workers.

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Introduction

In the almost two decades of conflict following September 11, 2001, resilience continues to be critically important to the United States Special Operations Forces (SOF) consisting of Army Green Berets, Navy SEALS, Marine Raiders, and Air Force Pararescuemen, combat controllers, and aviators.[1,2] Each of these elite units seek highly motivated candidates and train under extreme conditions to assess and prepare the operator for life in a SOF unit. Individuals joining special operations units experience stressors at the extreme ends of human mental, physical, and emotional endurance. Research suggests that to be successful in such units, individuals must possess unique characteristics and traits, including an "uncommon will to succeed"[3(p148)] and an uncanny ability to persist without support in the face of great adversity.[3] This research examines resilience, a psychological coping mechanism that fosters one's ability to recover from adversity,[4] at the initial assessment and selection course of the Navy's SOF component, Naval Special Warfare, also known as the Navy SEALs. For this study, SEAL candidates conducted self-assessments to record their psychological level of resilience as well as provided blood samples for physiological biomarkers (brain-derived neurotrophic factor (BDNF), dehydroepiandrosterone (DHEA), and cortisol) of resilience. This study utilized the demanding environment of SOF assessment to study both the psychological and physiological measures of resilience, which are often believed to be the critical components for successful completion of the selection process.

The study of resilience has been of particular interest to the military in order to understand the importance and benefits of resilience for military personnel

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negatively affected by sustained combat operations.[5–7] Beyond the military, the study of resilience has intensified over the last two decades with interest in using data from research of resilience to generate a more complete understanding of the construct to inform policy and practice.[8] Britt, Sinclair, and McFadden suggest resilience is a combination of competence, confidence, connection, character, contribution, coping and control, or an individual's ability to maintain a "positive adaptation in the face of adversity."[7(p3)] While psychological markers of resilience, defense mechanisms, have been explored since the 1800 s and the physiological markers, through homeostasis, have been studied since the 1920s, the resilience construct only emerged in the 1990s.[9] Tusaie and Dyer[9] believed that understanding resilience requires a dynamic, interactive perspective, that takes on a holistic approach to grasp the construct. Yet, most research into resilience examines the construct from either a psychological or physiological perspective; therefore, providing a somewhat myopic viewpoint.

The psychological aspects of one's coping ability are often measured through self-assessment instruments and interviews.[8,10] Studies have indicated the psychological resilience can be an indicator of performance in various settings, most specifically in athletics and academics.[10–13] While research has been conducted regarding psychological resilience within military contexts,[5,6,14,15] there have been few studies on resilience within SOF selection and assessment, and little research examining the underlying characteristics of resilience for progression within the SOF, and more specifically the SEAL community. According to Matthews,[16] resilience, as well as other similar psychological constructs, requires more extensive research within specific domains to explore the role these characteristics and traits have in demanding training situations. Since high stress is a component of the normal work environment in the SOF community and is especially present in SOF selection and assessment training, the study of resilience, the process of adapting to adversity and mitigating stress,[17] is of considerable importance to the SOF community.

Despite much discussion of the importance of resilience for overcoming sources of stress or trauma,[4,8] there is still little understanding of the outcomes or consequences of resilience.[18] This lack of understanding may stem from a lack of consensus regarding whether resilience is considered an outcome of facing adversity, or a process of adapting to adversity.[19] Connor and Davidson utilize a process approach to resilience, where resilience represents an individual's ability to remain in bio-psychospiritual homeostasis following disruptive and adverse events.[20] Ultimately, one's baseline resilience contributes to how the individual responds to adversity and can be further developed through that and/or other adverse events. This study utilized this process approach to psychological resilience, where one's baseline resilience may predict progression through an adverse event, as adverse events occur on a weekly and often daily basis during SOF selection and assessment rather than at one traumatic moment in time. The extreme environment of the initial SEAL training known as Basic Underwater Demolition/SEAL training, or BUD/S, which is the assessment and selection training on the pathway to become a SEAL, includes extensive physical exertion, activities with no-win outcomes, and a continuous haranguing by instructors.[21] In the intensive training environment, it is often presumed that one's baseline psychological traits drive one's persistence and perseverance through the arduous training, while at the same time being developed throughout the process.

In contrast to the psychological assessment, the physiological path to assessing resilience relies on examining specific physiological markers of stress.[9] Individuals entering BUD/S are already exceptional athletes, but this training can have a profound effect on their physiological processes as the body strives to maintain homeostasis.[22,23] A disruption of homeostasis triggers the activation of the hypothalamo-pituitary-adrenocortical (HPA) axis, the primary hormonal response to stress.[23] Stress resilience has been associated with HPA-axis regulation, with an optimal response during stress exposure accompanied by termination of the stress response once the stressor is no longer present.[24] Among many hormones involved, cortisol and dehydroepiandrosterone (DHEA) are released from the adrenal cortex in response to stress.[25] Cortisol increases arousal, enhances vigilance, and mobilizes energy stores whereas DHEA is known to offset the influence of cortisol, providing anti-inflammatory and neuroprotective effects.[25,26]

Previous research has demonstrated the importance of DHEA and the DHEA-to-cortisol ratio in stress resilience to prevent the harmful effects of prolonged cortisol activation, such as immunosuppression, and potentially buffer the severity of post-traumatic stress disorder (PTSD).[24–27] Additionally, both hormones have been shown to have strong correlations with performance during stressful military exercises.[28,29] For example, Morgan et al[29] reported a positive relationship between baseline DHEA and performance during a stressful underwater navigation test; especially applicable to the present study given the nature of BUD/S and the large portion of training in and under the water.

Along with DHEA and cortisol, brain-derived neurotrophic factor (BDNF) has received considerable attention with regard to stress resilience.[30,31] The brain is the primary organ of resilience as it is continuously receiving information from the environment and directs multiple organ systems to adapt.[32] Neurotrophic factors, specifically BDNF, are important in remodeling neural circuits to adapt to environmental demands by enhancing synaptic plasticity, neurogenesis, and neuronal survival.[33] Chronic stress has been demonstrated to down-regulate hippocampal BDNF and decreased circulating concentrations of BDNF have been observed in depressed patients.[30,34,35] BDNF concentrations in blood plasma have been shown to be significantly correlated with hippocampal BDNF in several mammalian species.[36] As a result, plasma BDNF concentrations may potentially serve as a proxy marker of neural plasticity. Interestingly, BDNF serves a similar function as DHEA in hindering adverse effects of glucocorticoid signaling from chronically elevated cortisol concentrations.[31] Given the profound physiological stress-induced during BUD/S, these key biomarkers may provide insight to biological variations to stress exposure, potentially elucidating individuals possessing stress resilience.

The purpose of this study was two-fold. One, to assess the role that the psychological trait of resilience plays in SEAL trainees' progression through the extremely rigorous phases of BUD/S training. Relative to this portion of the study, a self-assessment measure for resilience was utilized. Two, to utilize biomarkers indicative of biological stress to elucidate the biological signatures of physiological resilience. Relative to both measures of resilience the primary objectives were 1) identification of a predictive algorithm for resilience; 2) validation of algorithm during acute high-stress military conditions; and 3) exploration of biological indices indicative of resilience against the psychological stressors imposed during BUD/S. For this study, SEAL candidates conducted self-assessments to record their psychological level of resilience (i.e. the Connor-Davidson Resilience scale[20]) as well as provided blood samples for physiological biomarkers (BDNF, DHEA, and cortisol) of resilience.

To achieve these research objectives the study was driven by three hypotheses. Given that resilience has been found to affect one's ability to withstand the stresses of the military,[15,28,29] it is logical to assert those with higher resilience may have greater psychological and physiological tolerance of the rigors of BUD/S, and thus have a greater propensity to successfully progress through training. Thus, it was hypothesized:

Hypothesis 1: Successful completion of First Phase of the BUD/S is positively related to psychological measures of resilience.

Hypothesis 2: Successful completion of First Phase of the BUD/S is positively related to physiological biomarkers of resilience.

Because these traits manifest differently, it is also logical to assert that individuals with a higher combination of psychological and physiological resilience will demonstrate even greater tolerance of the rigors of BUD/S training. Thus, it was hypothesized:

Hypothesis 3: Successful completion of First Phase of the BUD/S is positively related to the sum of psychological and physiological measures of Resilience.

Methods

Sample, recruitment, and data collection

The sample consisted of SEAL candidates as they progressed through BUD/S, a program designed to identify candidates who can tolerate a variety of stressors while maintaining high physical and cognitive function.[21,37] This study examined students during their first two months of training, referred to as First Phase. Despite having premier athletes as candidates, the attrition rate during BUD/S is approximately 65–80%,[38] with the fourth week, known as "Hell Week" and one of the most arduous periods, having the highest dropout rate for any single week during training.[21,37] The sample size began at 116 participants. The measures for psychological and biomarkers for physiological resilience were collected during day four of First Phase of BUD/S training. IRB approval was granted through the primary researcher's institution. The research team, all of whom live and work in a different geographic location from San Diego, California where the training is located, was an external entity to the cadre who oversaw BUD/S training. As such, the researchers played no role in determining who completed BUD/S training. Prior to data collection, the relationship between the research team and the study participants was clearly defined, indicating that participation in the study played no role in

Table 1. Demographic table of participants representing education, age, race (N = 116).

Demographic	Number	%
Education		
High school	30	25.8%
1–3 years of college	30	25.8%
4 year degree	48	41.3%
Graduate education	6	5.1%
Age		
17–23	58	50.0%
24–26	39	33.6%
27–35	19	16.3%
Race		
Caucasian	97	83.6%
Multiple Races	8	6.8%
Hispanic or Latino	6	5.1%
African American	1	.9%
Asian	1	.9%
Native American or Pacific Islander	1	.9%
Identified as other race	2	1.7%

students' progression through BUD/S. Once the research team was introduced to the BUD/S class, the cadre of the class left the building, making it clear to participants that this was a voluntary study and the research team had no influence or power over the students' completion of the course. Each participant was provided with an informed consent form which included the purpose of the study, an explanation of the procedures involved in the study, explanation of anonymity, as well as emphasis regarding the voluntary nature of the study and the participants' ability to withdraw at any point from the study. Participants were also verbally provided the details of the informed consent by the primary researcher prior to the data collection session.

The majority of applicants were under 23 and had taken some college courses. Further, 83% were enlisted sailors and 17% officers, 84% of the sample identified as Caucasian, 5% as Hispanic or Latino, 2% as multiple races, and about 1% each identified as African American, Asian, and Native American or Pacific Islander (Table 1). At the completion of First Phase on the 54th day, the researchers obtained data regarding who had successfully completed this initial phase, those who withdrew or were eliminated due to performance (dropped), and those who had medical or administrative reasons for being unable to complete First Phase (rolled). Of the 116 participants, 54 successfully completed First Phase; approximately 57% of the candidates who did not complete training were voluntary withdrawals or had performance issues, while the other 43% left for medical or administrative reasons. The 57% of the candidates that withdrew or had performance issues were of special interest for this study as participants with potential deficiencies in resilience.

Measures

Control variables

Common control variables include age, education, and gender since they may affect the outcome variable of interest.[39] Historically, Navy SEAL trainees are a homogeneous group, in which there is currently no variability in gender and minimal difference in additional demographics, such as race and education. Further, researchers indicate that there should be specific reason behind the inclusion of any control variables in one's analysis.[40,41] As such, this study focused specifically on two control variables, age and social desirability. Age was utilized as a control for maturation, in which an older individual may be more prone to injury. Conversely, an older individual with varied life experiences may respond differently to the rigors of BUD/S.

One concern in social science research is with respondents providing responses that those individuals believe to be desirable and favorable.[42,43] Responses of this sort fall under what researchers consider social desirability bias.[43] The respondents were all in the Navy, drawn to an occupation of selfless service, have a high duty concept, and most are assumed to be intrinsically motivated versus doing things for a reward.[44] However, due to the intensive selection process for Navy SEALs, the researchers sought to control for participants providing desirable and favorable responses. In this study, the researchers focused on scale selection, assessed instrument construction, instrument administration, and utilized statistical control techniques with a social desirability scale as a control variable.[45,46] For this purpose, the Crowne and Marlowe[47] social desirability scale was utilized. It is a 33-item scale which was utilized as a way to examine the quality of participants' responses and mitigate the propensity to give the socially correct answer, instead of the respondents' true feelings. The Cronbach alpha was $\alpha = 0.749$ for the social desirability scale.

Independent variables

The assessment of resilience involved two measures: a self-report survey, which is a psychological assessment of the resilience traits,[20] and a blood draw to determine levels of cortisol, DHEA, and BDNF as physiological biomarkers that have been previously associated with stress adaptation and neuronal integrity.[25,26,48] All measures for the present study are well-known instruments in the research literature on resilience.

Psychological measure of resilience

The psychological measure of resilience utilized was the Connor-Davidson Resilience Scale (CD-RISC), a 25-item self-rating scale[20] measuring each participant's agreement to statements designed to capture tacit resilience. Questions reflect concepts such as adaptability to change, past success and confidence, one's response to failure, sadness and fear, as well as the ability to attain goals. The measure returns a resilience rating of 0 to 100, with higher scores suggesting greater psychological resilience.

The CD-RISC is a popular measure of resilience. A study of the psychometric properties of the CD-RISC in a sample of 53,692 U.S. Air Force enlisted basic trainees, confirmed strong internal consistency of the scale and indicated its predictive validity relative to attrition in military service.[49] To test the internal consistency of the CD-RISC in this study, the maximum likelihood estimation was the model of choice. Factors were extracted utilizing the fixed number of factors method, with a direct Oblimin rotation.[50] Direct Oblimin rotation is of interest in this case because it allows the axis to rotate other than orthogonally, as in nature when factors are unrelated. Other factor analysis rotations require orthogonal correlations (Varimax, Quartimax, and Promax). The output provides coefficients sorted by size, which helps the interpretation of the factors. Previous literature supports the utilization of this 25-item measure as one factor,[49] and a Cronbach alpha was conducted for completeness and found to be $\alpha = 0.817$. Such a finding is consistent with the literature for internal consistency and reliability.[51,52]

Physiological indicators of resilience

For physiological indicators of resilience, a 21-gauge needle (BD Vacutainer ® Eclipse and Vacutainer ® one-use holder, Becton, Dickinson and Company, Franklin Lakes, NJ) was used to collect 12 mL of blood at baseline data collection (First Phase, day 4) and placed into appropriate collection tubes (SST and EDTA BD Vacutainer®, Becton, Dickinson and Company Franklin Lakes, NJ) by trained Navy corpsmen. Due to limited access to participants and the rigorous training schedule, all participants' blood was drawn between 1600 and 1800 in a non-fasted, post-physical exertion state. Serum was obtained from the SST tubes by allowing the blood to clot for 30 minutes then centrifuged at 1500 g for 15 minutes at room temperature. Plasma obtained from EDTA tubes were centrifuged immediately after collection at 1500 g for 15 minutes at room temperature. Supernatant of plasma and serum samples were aliquoted into 500 mL Eppendorf tubes, packed on dry ice and shipped overnight to a certified testing lab. Samples were stored at -80 °C until ELISA assays were conducted for DHEA (Eagle Biosciences, Amherst, NH), cortisol (ALPCO, Salem, NH), and BDNF (EMD Millipore, Bullerica, MA). All assays were conducted in duplicate and all CV's were below manufacturers reported variance (10%) and above the assay level of sensitivity, which was 0.15 ng/mL for DHEA, 0.4 µg/dl for cortisol, 0.23 pg/mL for BDNF. There were four independent variables indicative of physiological resilience: DHEA, BDNF, cortisol, and a ratio of DHEA-to-cortisol, resulting in an average of 109 observations across the four variables.

Dependent variable

Given that the goal of this research was to determine psychological and physiological factors that may influence one's overall ability to complete the First Phase of BUD/S, the comparison groupings for the Analysis of Variance (ANOVA) were if a person was actively enrolled in training on day 54, the final day of First Phase. If a service member was not present on day 54, he had either been dropped or rolled from training. Dropping occurred when a service member quit, underperformed, or was not mentally or physically capable of completing training. Rolling occurred when a service member was hurt, or otherwise unable to continue (for many reasons), but they would rejoin the training with a subsequent class. In the ANOVA, the outcome was specified 0 for those who remained in the training, and 1 for those who were no longer with the original training class (dropped or rolled).

Because this research has two separate analyses, it was necessary to operationalize the outcome variable slightly differently for the regression models. To that end, for the linear regression model the outcome variable was operationalized as the number of days of training a service member completed, creating a continuous outcome variable. In the sample the maximum days completed of training was 54, and the minimum days completed was 6 days.

Data analysis

To determine the psychological and physiological differences between those remaining in the training, it was necessary to examine the data through the lens of an ANOVA, and through a linear regression. Thus, given both tests required the data to comply with the central limit theorem, which suggests data should be

Table 2. Descriptive statistics and analysis of variance (ANOVA) for biomarkers of resilience and psychological resilience.

		Descriptive Statistics					ANOVA	
IV	Outcome	*N*	Mean	Std. Dev	Std. Error	95% CI for the Mean	F	Sig
BDNF (pg/mL)	Enrolled	45	230.98	70.88	10.57	(209.69; 252.28)	0.119	0.73
	Dropped/ Rolled	63	225.30	66.04	8.32	(208.67; 241.93)		
	Total	108	227.67	67.83	6.53	(214.73; 240.61)		
DHEA (ng/mL)	Enrolled	45	2.20	0.63	0.09	(2.01; 2.39)	7.61	0.00*
	Dropped/ Rolled	57	1.93	0.33	0.04	(1.85; 2.02)		
	Total	102	2.05	0.50	0.05	(1.95; 2.15)		
Cortisol (ug/dL)	Enrolled	45	13.15	6.97	1.04	(11.06; 15.25)	1.191	0.28
	Dropped/ Rolled	62	11.96	4.38	0.56	(10.84; 13.07)		
	Total	107	12.46	5.62	0.54	(11.38; 13.54)		
DHEA/Cortisol	Enrolled	39	0.21	0.06	0.01	(0.19; 0.23)	20.882	0.00**
	Dropped/ Rolled	55	0.16	0.05	0.006	(0.15; 0.17)		
	Total	94	0.18	0.06	0.006	(0.17; 0.19)		
Psychological resilience	Enrolled	47	83.66	7.87	1.15	(81.35; 85.97)	0.448	0.51
	Dropped/ Rolled	66	82.64	8.11	0.998	(80.64; 84.63)		
	Total	113	83.06	7.99	0.75	(81.57; 84.55)		

$^{*}p<.01$.
$^{**}p<.001$.
Standardized values are provided in parentheses.

normal, it was necessary to delete outliers in the data set resulting in approximately 104 remaining participants, or a sample rate of 87%. The results include all observations falling within 98.6% (plus or minus 2.5 standard deviations) from the mean.

Results

Descriptive statistics

The sample is described through the ANOVA in Table 2 reflecting the control variable of social desirability, as well as each participant's concentrations of BDNF, DHEA, cortisol, DHEA-to-cortisol ratio, and psychological resilience. Only two of the five factors showed statistically significant differences between those who continued to be enrolled and those no longer enrolled (either dropped or rolled). Specifically, the average concentrations of the biomarkers BDNF and cortisol both suggest those who successfully completed First Phase have slightly higher levels of BDNF (230.98 vs. 225.30 pg/mL) and cortisol (13.15 vs. 11.96 μg/dL) than those that were either dropped or rolled, however, those values were not statistically significantly different. Conversely, when considering the binomial outcome of enrolled (meaning the candidate remains enrolled), dropped/rolled (meaning the candidate was either dropped from training or rolled back into a later training group) levels of DHEA were statistically significantly different between groups (DHEA: 2.20 and 1.93 ng/mL, $p < 0.01$). Similarly, considering the DHEA-to-cortisol ratio was also statistically significantly higher in those who remained enrolled at the end of First Phase versus those that were dropped or rolled (DHEA-to-cortisol ratio: 0.211 vs 0.160, $p < 0.001$). Interestingly, while psychological resilience was not statistically significantly different for those enrolled, versus those dropped or rolled, the measure was statistically different when regression was utilized, which is considered a higher-powered statistical test.

To address standardized effect sizes, the independent variables were considered in their standardized forms. Of note, when the ratio of DHEA-to-Cortisol is converted to a standardized z-score, it illuminated the difference between the groups. For example, the people who remained enrolled in BUD/S training had an average DHEA-to-Cortisol ratio of 0.537, while those who dropped or rolled had an average of −0.324 (as provided in Table 2), a difference of almost a standard deviation. Similarly, the psychological scale of resilience suggests those remaining enrolled in BUD/S through First Phase have an average resilience score of 0.075, while those who dropped or rolled had an average of −0.053. Written this way, it is clear that while these are only two factors of many involved in the road to completion of First Phase of BUD/S, they seem to have played a role in successful completion of this phase of training.

Regression analysis

Hypothesis 1 indicated that higher psychological resilience would be observed in participants finishing First Phase (54 days). Utilizing a hierarchical linear regression model, Hypothesis 1 was supported. As specified in Table 3, Model 2, after controlling for age and social desirability, for each one unit increase in

Table 3. Linear regressions for psychological resilience, biomarkers of physiological resilience, and psychological and physiological markers of resilience.

	Model 1					Model 2					Model 3					Model 4				
	B	SE B	β	t	Sig	B	SE B	β	t	Sig	B	SE B	β	t	Sig	B	SE B	β	t	Sig
Age	0.80	0.47	0.18	1.70	0.09	0.91	0.46	0.20	1.96	0.05	0.71	0.45	0.16	1.58	0.12	0.86	0.44	0.19	1.93	0.06
Social Desirability	−0.17	0.34	−0.05	−0.51	0.61	0.01	0.34	0.004	0.04	0.97	−0.20	0.32	−0.06	−0.62	0.54	−0.04	0.33	−0.01	−0.11	0.914
Psychological Resilience						0.44	0.19	0.24	2.27	0.03*						0.42	0.19	0.23	2.29	0.02*
DHEA/Cortisol											72.26	25.50	0.29	2.83	0.01**	73.55	25.19	0.29	2.92	0.00**
F				1.666	0.20				2.872	0.04*				3.841	0.01*				4.472	0.00**
R^2				0.036					0.090					0.116					0.172	
Adjusted R^2				0.015					0.059					0.086					0.134	
ΔR^2									0.054					0.080					0.082	
ΔF									5.128	0.03*				8.032	0.01**				8.526	0.00**

N = 90.
*$p < .05$.
**$p < .01$.
Outcome variable was measured as days of training completed, the minimum days of training completed was 6 days and the maximum days completed was 54 days.
ΔR^2 for Model 2 and Model 3 is relative to the change from Model 1.
ΔR^2 for Model 4 is relative to the change from Model 2.

psychological resilience, we expect BUD/S candidates to complete about 4.02 more days of training ($\beta = 0.239$). The regression analysis suggested the model containing age, social desirability, and one's psychological resilience accounted for about 9% of the variance in one's ability to remain enrolled in BUD/S through First Phase *[t = 2.265, p < 0.05]*. The addition of psychological resilience to the model with age and social desirability (Model 2), provided an additional explanation of 5.4% of the variance in days completed beyond the model containing age and social desirability alone (Model 1), statistically significant at *(ΔF = 5.128, p < 0.05)*.

To address the question posed in Hypothesis 2, physiological biomarkers of resilience were examined to investigate their relationship to one's ability to complete First Phase of BUD/S (54 days). In order to operationalize the physiological manifestation of resilience, a ratio of DHEA-to-cortisol was utilized. As can be seen in Table 3, Model 3, after controlling for age and social desirability, Hypothesis 2 was supported. Specifically, for each one unit increase in the DHEA-to-cortisol ratio, we expected to see an increase of about 4.3 days of training ($\beta = 0.285$). Moreover, the model that contained age, social desirability, and DHEA-to-cortisol ratio (physiological resilience), accounted for about 11.6% of the variance in one's ability to remain enrolled in BUD/S through the completion of First Phase *[t = 2.834, p < 0.01]*. The addition of physiological resilience to the model with age and social desirability (Model 3), provided an additional explanation of 8.0% of the variance in days completed in BUD/S beyond the model containing age and social desirability alone (Model 1), statistically significant at *(ΔF = 8.032, p < 0.01)*.

Hypothesis 3 investigated the impact of psychological and physiological resilience on one's ability to successfully complete First Phase of BUD/S (54 days). Utilizing a hierarchical linear regression model and controlling for age and social desirability, the present research found support for Hypothesis 3. As is provided in Table 3, Model 4, after controlling for age and social desirability, and utilizing the standardized coefficients (due to the large scale differences in the variables of psychological and physiological resilience) for each one unit increase in psychological *and* physiological resilience (DHEA-to-cortisol ratio), there was an increase of about 8.2 days in BUD/S training. The results predict approximately 17.2% of the variation in days completed during First Phase of BUD/S. The addition of physiological resilience to the model with age, social desirability, and psychological resilience (Model 4), provided an additional explanation of 8.2% of the variance in days completed in BUD/S beyond the model containing age, social desirability, and psychological resilience (Model 2), statistically significant at *(ΔF = 8.526, p < 0.01)*.

It is also important to note that in the ANOVA table (Table 2) DHEA, and DHEA-to- Cortisol were both statistically different for the two groups: enrolled, and dropped/rolled. However, when a more sensitive statistical test was utilized (the regression model) with a continuous outcome variable, we see statistical significance associated with the psychological measure of resilience as well.

Discussion

This study provides a unique contribution to the literature as it examines one of the military's most arduous and stressful training environments in which resilience plays a critical role in successful completion. It is part of the emerging research into the combined measures of psychological and physiological manifestations of resilience.[53] In addition, this study provides a contribution to the literature in four important ways. First, it addresses Matthews'[16] call for more extensive research into the psychological resilience construct within demanding training. Second, it contributes to the nascent literature into physiological biomarkers for resilience and how those markers may be utilized as predictive of performance. As such, it addresses Osório et al's[48] implication that understanding the physiological markers of resilience may assist researchers in establishing a resilient profile for individuals who operate in high-stress environments. Third, this study has determined that combining the psychological and physiological resilience into a single metric has a greater ability to assess resilience as both a cognitive and physiological measure. Fourth, this study validates with empirical evidence the importance resilience plays in the completion of extremely demanding military training.

In this study, each of three hypotheses were supported. The first hypothesis was that success in First Phase was positively related to psychological resilience. Findings suggested the model with psychological resilience accounted for 9.0% of the variance in one's ability to complete First Phase. Although different in context and methodological approach, this finding provides support for studies that have examined the role psychological resilience plays in performance.[10–13] Windle[18] contended that despite much research and interest into resilience, there are deficiencies in the research relative to the outcomes or consequences of resilience. This study begins to address some of those deficiencies. Utilizing a process perspective of psychological resilience,[20] the researchers theorized individuals have a baseline level of psychological resilience, which would contribute to an individual's ability to persist through arduous training. The findings from this study supported this theory, those with higher levels of baseline resilience were more apt to persist to Second Phase. Future research should expand upon this process perspective of psychological resilience by examining how baseline resilience develops over time in arduous training situations such as BUD/S.

The second hypothesis, completion of First Phase is positively related to physiological biomarkers of resilience, was also supported. In this study, the model with DHEA-to-cortisol ratio, physiological resilience, accounted for 11.6% of the variance in one's ability to successfully complete First Phase. This ratio represents a surrogate for the relative proportion of anabolic to catabolic hormones,[28] in which DHEA counters the harmful effects of sustained elevated cortisol.[26] Therefore, it is plausible that a higher DHEA-to-cortisol ratio is advantageous for physiological stress management during rigorous training. Similarly, previous research has demonstrated increased DHEA-S (the sulfate derivative of DHEA)-to-cortisol ratios in active duty soldiers were associated with higher levels of performance during acute stress exposure in military survival school.[28] Likewise, in a similar study, baseline DHEA and DHEA-S were significant predictors of performance in an underwater navigation task during a combat diver qualification course.[29] As suggested by Shia et al.,[54] this ratio may not only help to identify resilient operators, but also to monitor operator stress, and provide insight to strategies geared toward improving the DHEA-to-cortisol ratio.

The third hypothesis was also supported, completion of First Phase was positively related to the sum of psychological and physiological resilience. The model with the combination of psychological resilience and DHEA-to-cortisol ratio accounted for 17.2% of the variance in one's ability to complete the first two months of BUD/S. Ultimately, this finding indicates that both psychological and physiological resilience are contributors to successful completion of difficult training environments. The holistic combination of the psychological and physiological aspects of resilience is just emerging in the literature.[53] In one of the early studies that combined psychological indicators of resilience with physiological, Tugade and Fredrickson[55] revealed that higher levels of psychological resilience contribute to one's ability to recover in a cardiovascular manner, a physiological marker of resilience.

Although the study indicated that 17.2% of the variance in the completion of training was accounted for by the combination of psychological and physiological resilience, there are indeed other factors that contribute to successfully progressing through BUD/S training. One of the other factors that could contribute is the specific class dynamic that either enhances or erodes individual resilience. Social support is a known pillar of individual resilience [24,56] and the inter-student support does vary and provides a large contribution to getting through training. Another factor that can also be a contributor to variability in successful completion is the instructor intensity. Although there have been efforts to provide a consistent intensity to training, there is some variability with certain instructors that bring a higher level of stress on the students than others. The make-up of the instructor staff changes in small increments from class to class can also provide some level of variability in the results. Finally, the cycle of weather is also believed to be a factor that may impact resilience to some degree. Within the SEAL Teams, there is a point of pride associated when each trainee experienced Hell Week, either in the summer or winter. Although the San Diego weather and temperature of the Pacific Ocean do not change dramatically over the seasons, it is enough to alter the conditions for the students. These external factors represent some of the other possible elements that could account for the additional variance in the trainees' ability to continue through BUD/S training.

Overall, it can be said that this study contributes to a broader understanding of the resilience construct. By examining resilience from both a psychological and physiological standpoint, this study provides empirical support for a dual structure of resilience as a dynamic, interactive process that is comprised of both psychological and physiological elements in lieu of simply one or the other.[9,53] Essentially, viewing resilience through a singular lens limits the understanding of resilience as a dynamic process.[9,48,53] With these findings, more research may provide additional insights into the role of psychological and physiological resilience in SOF and other population groups enduring reoccurring stressful and arduous experiences, such as competitive athletes, emergency personnel, and medical professionals. Further, continued research is encouraged in psychological and physiological resilience as individual constructs, as well as a combined measure.

While this study provides a unique contribution to the literature, there are several limitations that must be noted. First, psychological resilience was self-reported. A concern with self-report measures is that respondents may provide responses that they believe to be desirable and favorable.[43,46] In an effort to minimize the impression management responses sometimes occurring with self-report scales, a social desirability measure was included to control for this risk.[46] Second, due to scheduling limitations, the data was collected in the late afternoon on day four of First Phase. Relative to psychological resilience, there is the potential that the trainees took a different viewpoint of the items that measured resilience a few days after the rigorous training began than they would have prior to the start of training. Relative to the biomarkers of resilience, acute exercise has been shown to increase concentrations of BDNF,[57] as well as diurnal and exercise related fluctuations in both DHEA and cortisol. Thus, there is the potential that the indicators for resilience may have been different if collected the day before BUD/S commenced. The third limitation relates to the amount of baseline data collected for each participant. Due to the limited amount of time provided to collect data, it was only possible to collect basic demographic data. More detailed qualitative information regarding participants' past history, experiences with hardship, and family background would have added to the robustness of this study, but was not possible due to scheduling restraints related to participants' training schedule. The fourth limitation of this study relates to generalizability. As this is the first study of its type focused on United States SOF, specifically BUD/S trainees, the homogeneity was helpful in the development of this research, but it is not clear if the findings from this preliminary study would be representative of other training programs.

Conclusions

This study contributes to the nascent research into identifying biomarkers for resilience,[26,29,48] thus, contributing to a resilient profile from a physiological perspective. Further, the finding of the combination of psychological and physiological resilience explained almost twice the variance than either psychological or physiological resilience alone and provided support for this unique two-pronged approach to resilience in demanding training. It should be noted, however, that even when considering the psychological and physiological manifestations of resilience, about 80% of the variance is unexplained. While the results are encouraging, it is important that they be considered as merely the beginning to a larger body of research. Research should continue to focus on strengthening the data presented, through replication studies, as well as investigate additional measures of traits and characteristics, such as grit, hardiness, and mindfulness, that may further elucidate how one is able to progress through arduous training environments.

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